# MINERAL ACTIVATION: TOWWARDS THE DEVELOPMENT OF A $CO_2$ SEQUESTRATION MODULE

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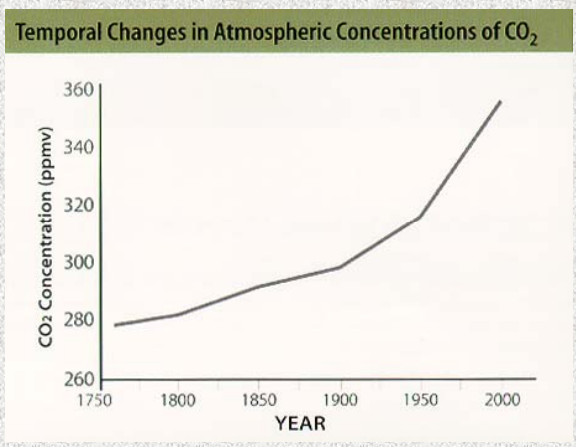
## Global Warming?




Los Alamos National Laboratory

# 21st Century Energy Plant

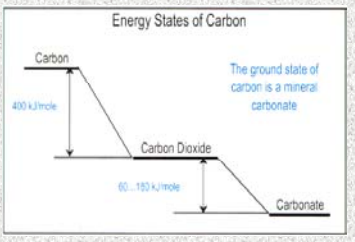
Vision 21, DOE, USA

No environmental impact: Zero $CO_2$ emissions



# Sequestering $CO_2$: Mineral Carbonation

$$Mg_3Si_2O_5(OH)_4 + 3CO_2 \rightarrow 3MgCO_3 + 2SiO_2 + 2H_2O$$

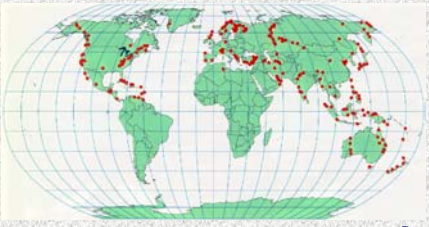



NETL, DOE

- Reaction of $CO_2$ with non-carbonate minerals, such as olivine and serpentine, to form stable and permanent mineral carbonates.
- Seen in nature as the aging of rocks, the process occurs naturally over geologic time scales.

# Mineral Sequestration: Advantages

- $CO_2$ is transformed into a STABLE and permanent mineral carbonate: No future legacy implications.
- Overall reaction is EXOTHERMIC: Potential to be economically viable upon further research.
- Potential to produce additional VALUE-ADDED by-products during the carbonation process: Cost effectiveness



- The raw minerals for sequestering the $CO_2$ exist in VAST, readily accessible quantities.



# Mineral Sequestration: Obstacles

- KINETICS - Innovative development of fast reaction routes under milder regimes in a continuous integrated process must be made.
- EFFICIENCY - Current carbonation studies require prior capture of the $CO_2$, high pressures, and extensive mineral particle communition, all energy-intensive operations.

# Research Objective

## ACTIVE CARBONATION

- Promotes and accelerates REACTION RATES and EFFICIENCIES through surface activation to the extent that extensive mineral particle communition and $CO_2$ capture from flue gases are not required prior to sequestration.
- SURFACE ACTIVATION to accelerate the carbonation reaction efficiency.

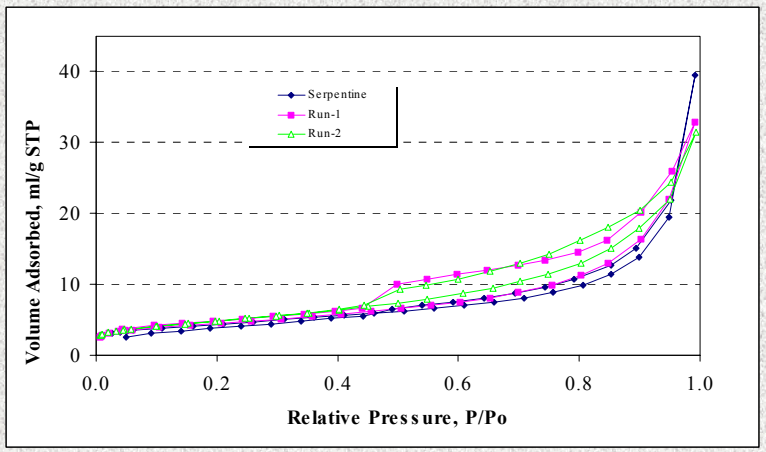


# Experimental

- The Cedar Hills **serpentine** (antigorite) sample was obtained from the Pennsylvania/Maryland state line district.
- **Porosity:** $N_2$ at 77K and $CO_2$ at 273K adsorption isotherms using a Quantachrome adsorption apparatus, Autosorb-1 Model ASIT.
- **SEM studies**: HITACHI S-3500N, where the accelerating voltage was 20KV and magnification was 1500X.
- **X-ray diffraction**: Range of 9.0 to 65.0 degrees at a step scan rate of 0.07 degrees per minute using a Scintag Pad V unit.
- **High pressure TGA**: Cahn TG151, where the weight change of the sample, either as a solid or in solution, is monitored in a $CO_2$ atmosphere with pressures up to 1000psi.
- **Carbonation studies**: CSTR reactor used for the parent and activated samples.

# Mineral Activation-1

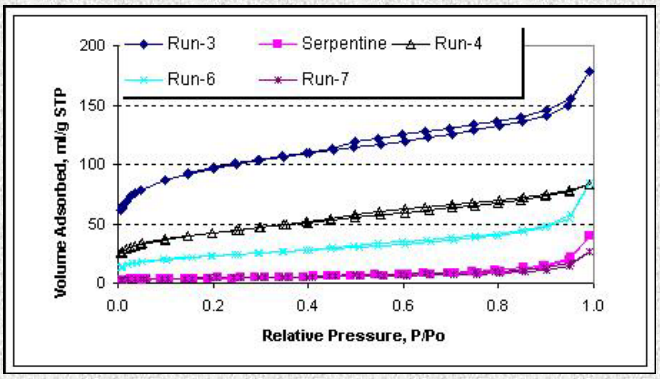
## $N_2$ adsorption isotherms at 77K



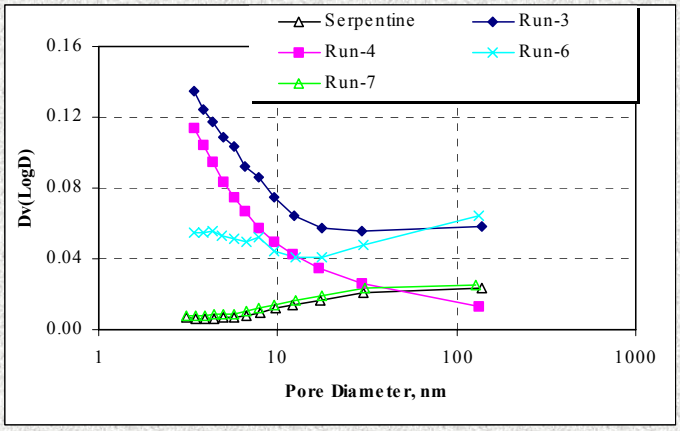



# Mineral Activation-2

## $N_2$ adsorption isotherms at 77K

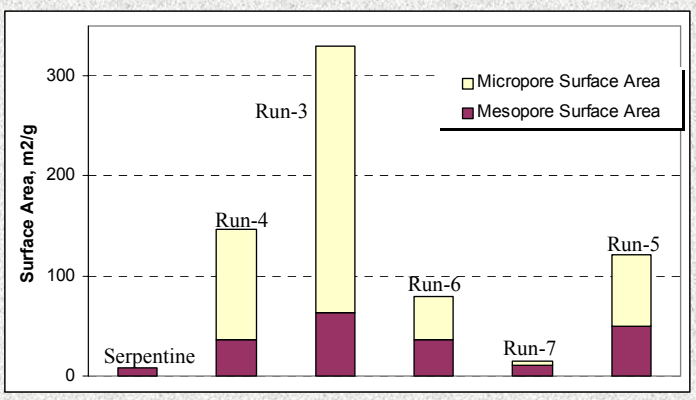


# Pore Size Distribution






# Surface Area Distribution



# Summary of porosity data

| Sample | BET surface area m2/g | Pore Volume ml/g | Average Pore Diameter nm |
|---|---|---|---|
| Untreated sample | 8 | 0.017 | 8.5 |
| Run-1 | 16 | 0.035 | 7.9 |
| Run-2 | 17 | 0.034 | 7.9 |
| Run-3 | 330 | 0.234 | 2.8 |
| Run-4 | 147 | 0.120 | 3.3 |
| Run-5 | 122 | 0.097 | 3.2 |
| Run-6 | 104 | 0.092 | 3.5 |
| Run-7 | 15 | 0.023 | 6.1 |



# Magnesium solubility

| Treatment | % Mg2+ in solution | Conditions |
|---|---|---|
| Run-3 | 71 | 25°C, 12 hours |
| Run-6 | 21 | 25°C, 12 hours |
| Run-5 | 25 | 25°C, 12 hours |
| Acetic acid | 48* | 60°C, 4 hours* |

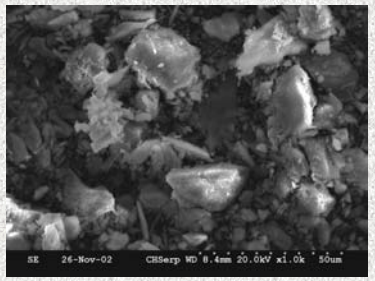
*Maximum extraction yield reported in the literature using acetic acid (Kakizawa et al., 2001)

# Carbonation experiments

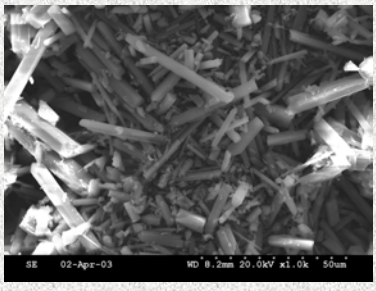
| Sample | % Conversion | Carbonation conditions |
|---|---|---|
| Parent | 8 | 155°C, 1850psig, 1 hour |
| Run-1 | 70 | 155°C, 1850psig, 1 hour |
| Run-8 | 73 | 20°C, 650psig, 3 hours |
| Run-9 | 54 | 20°C, 650psig, 6 hours |
| Run-10 | 30 | 20°C, 650psig, 3 hours |



# SEM Characterization




Raw serpentine




Carbonation Product

# Conclusions

- Serpentine minerals have been identified as suitable feedstocks for the mineral carbonation.
- It is possible to increase the surface area of the serpentine minerals to 330$m^2$/g, compared to only ~8$m^2$/g for the raw serpentine.
- Following mineral activation, the carbonation reactions can be conducted under mild conditions (20°C and 650psig) compared to previous studies that required >185°C, >1850psig.

*Provisional patent submitted*



# Acknowledgements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